THE VARIATIONS AND GENETIC PATTERNS OF FOUR QUANTITATIVE CHARACTERS OF RICE UNDER DIFFERENT ENVIRONMENTAL CONDITIONS [2)]

by

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Introduction

Comstock and Moll (1963) classfied environmental variations into two categories: (a) macro-and (b) micro-environmental variations. Macro-environmental variation is caused by fluctuation in variables i.e. years, locations, fertility levels, planting dates etc. which have large and easily recognized effects. Micro-environmental variation arises from plot-to-plot variability within macro-environments. Frey (1964) used "stress" to describe environmental conditions that curtail or limit plant productivity. Stress can be caused by many factors, i.e. drought, low fertility, disease epiphytotics, etc.. Then what factors constitute an optimum environment in which to practice selection for certain desirable characters during the course of plant breeding? Obviously, the optimum environment is one which will elicit the greatest different genetic manifestation for the character under selection.

Many research workers considered that spacing and nitrogen fertilizer are two important factors to determine grain yield of rice; and indicated that higher yield is obtained from close spacing and high level of nitrogen fertilizer application. This is of great significance to rice production in Taiwan. How to develop a variety which may best fitted to grow under such condition is the matter of an urgent importance.

The present study is to look into the genetic performance of four agronomic characters in the segregating population under different environmental conditions.

Materials and Methods

Two ponlai varieties, IG-65-1 (isogenic line from Taichung No.65) and P167 (Pai-kan-tao) were used in this study. About 30 parental plants and 300 F_2 plants were cultivated in the experimental fields at first crop of 1968. The materials were planted in three different plots. Two levels of nitrogen fertilizer and two spacings, ploted in incomplete factorial arrangement. The two levels of nitrogen are $N_1=80$ kg/ha, $N_2=120$ kg/ha, of ammonium sulfate; the other two elements are the same, i.e. $P_2O_5=60$ kg/ha of calcium super-phosphate and $K_2O=80$ kg/ha of potasium sulfate. The two spacings are 22.5 cm × 22.5 cm (S_1) and 22.5 cm × 11.25 cm (S_2)

The data on plant height, panicle number, panicle length, and panicle weight per plant were collected at the harvest and after air drying. F-test and t-test are used for comparing variances and means of any two populations, respectinely. Heritability value was estimated in the broad sense.

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Experimental Results

I. Inheritance patterns of characters under different environmental conditions

1. Plant height

The means, variances and frequency distributions of parents and F_2 populations are given in Table 1. As shown in Table 1, the differences of variances between $S_1 N_1$ and S_1N_2 in F_2 populations are significant at one-percent level. The others are statistically nonsignificant. The mean differences of parents and F_2 populations as shown in Table 5, there is no differences between treatments for IG-65-1, but highly significant for Pai-kan-tao. The differences between S_1N_1 and S_2N_1 in F_2 populations are found to be highly significant. The above results indicated that increased amount of nitrogen fertilizer caused the differences of variations, and increase of means. It was noticed that the influence of fertilizer is stronger than that of spacing.

Table 1. The means, variances and frequency distributions for plant height of parents and F_2 population at three different environmental conditions.

Treatment	Population	Upper limit of class, cm										Total	$\bar{X}$	S^2
		85.0	90.0	95.0	100.0	105.0	110.0	115.0	120.0	125.0	130.0			
S_1N_1	P_1					1	4	6				11	110.3	13.26
	F_2	1		2	6	13	31	31	14	2		100	109.7	38.57
	P_2	2	6	1	1	1						11	89.8	21.29
S_1N_2	P_1					2	3	4	1			10	109.4	21.38
	F_2	1	1		2	5	16	31	31	11	2	100	113.5	67.08
	P_2		1	3	5							9	95.0	8.61
S_2N_1	P_1				1	1	3	2				7	107.3	32.57
	F_2	1		3	7	11	23	21	26	6		98	110.6	61.34
	P_2			4	2	1	1	2				10	100.5	81.61

P_1=IG-65-1 S_1=22.5cm×22.5cm N_1=80:60:80
P_2=Pai-kan-tao S_2=22.5cm×11.25cm N_2=120:60:80 kg/ha for $N:P_2O_5:K_2O$

The segregation of plant height in F_2 showed a 3 high:1 low ratio in all three treatments indicating the monogenic mode of inheritance. But the dividing point for high and low height was found to be at 105 cm for S_1N_1 and S_2N_1, and that was found to be at 110 cm for (S_1N_2). This discrepancy might be due to the environmental modifications.

The heritability value of plant height was estimated to be 76.96% (S_1N_2), 29.96% ($S_1 N_2$) and 6.93% (S_2N_1), respectively. These three values indicated that under the increased amount of nitrogen fertilizer condition, the selection for plant height is more effective

than that under different spacing.

2. Panicle length

The data on means, variances and frequency distributions of panicle length are given in Table 2. As shown in Table 2, the difference of variances between different treatments in F_2 populations is highly significant for S_1N_2 and S_2N_1, but not significant for the others. The mean value of panicle length as shown in Table 5, there is only a slight difference between S_1N_1 and S_1N_2; S_1N_2 and S_2N_1, but no difference between S_1 N_1 and S_2N_1 in parental populations. In F_2 populations, no difference in panicle length between S_1N_1 and S_1N_2 was found. However difference between S_1N_1 and S_2N_1, and S_1N_2 and S_2N_1 was found to be at 1% level of significance. The above mentioned results indicated that close spacing significantly reduced the length of panicle; the means of parents is slightly affected by the increased application of nitrogen but no such effect was found in the F_2 populations.

If we group panicle length into short (less than 18.0 cm) intermediate (18.0–21.0 cm) and long (larger than 21.0cm) groups in S_1N_1, according to the frequency distribution curves, the observed numbers of plants falls 23, 45 and 27, respectively. These numbers fit well to 1:2:1 ratio which show non-dominant effect of monogenic inheritance. Same genetic mode is found in S_1N_2, but the dividing points are 17.0cm and 20.0cm. The observed frequencies are 21:53:26 which again fit well to 1:2:1 ratio. The segregation pattern, however is different in spacing plot, 68 plants fall in long-length group and 30 plants fall in short-length group. This was fitted into a 3:1 ratio which probably be due to environmental modification under the stress of spacing.

Table 2. The means, variances and frequency distributions for panicle length of parents and F_2 populations at three different environmental conditions.

Treatment	Population	Upper limit of class, cm												Total	$\bar{X}$	S^2
		14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0			
	P_1		1		3	3	1	1	2					11	18.1	3.52
S_1N_1	F_1	1	1	5	8	13	17	28	17	9		1		100	19.2	3.06
	P_2	1	3	4	1	1	1							11	15.8	2.80
	P_1					3	1	1	2	1	1	1		10	20.2	4.64
S_1N_2	F_2		4	8	9	12	20	21	13	9	2	1	1	100	19.1	4.24
	P_2		2		3	2		1	1					9	17.6	4.03
	P_1				3	3	1	2		1				10	18.2	2.53
S_2N_1	F_2	2	9	10	9	30	22	11	3	2				98	17.6	2.66
	P_2	2		4	3				1					10	16.0	3.74

All three heritability values estimated are zero. It is due to the large variation of

parents, indicating that this character is appreciably influenced by environmental conditions and the selection should be practiced in later generations.

3. Panicle number

The means, variances and frequency distributions for panicle number per hill of parents and F_2 populations at three fifferent environmental conditions are given in Table 3. The difference of variances between treatments in both parents, and F_2 populations is not significant as shown in Table 5, the differences between means of panicle number in IG-65-1 under different treatments are significant at 5% or 1% level, but no difference was found in Pai-kan-tao. The mean number of panicle in F_2 populations are 9.28 for S_1N_1, 11.36 for S_1N_2 and 7.71 for S_2N_1, respectively. The differences between these three values are all significant at 1% level. These results indicated that when amount of nitrogen is increased, the number of panicles per hill is also increased, but when spacing is close the panicle number is also reduced.

When panicle number is grouped into small (9 per hill or less) and large (more than 10) groups in S_1N_1, then the observed frequencies are 53 and 47 which fit well to a 9:7 ratio, indicating that two complementary genes conditioning the difference of two parents. The two complementary gene hypothesis is also fit well in the case of other two treatments.

The heritability values estimated for S_1N_1, $S_1 N_2$ and $S_2 N_1$ are 12.68%, 51.33 % and 2.21%, respectively. The value estimated in S_1N_2 is the highest among the three, indicating that the condition selection for panicle number is more effective under higher nitrogen levels. Even though, this character is known to be easily affected by environmental conditions.

Table 3. The means, variances and frequency distributions for panicle number per hill of parents and F_2 populations at three different environmental conditions.

Treatment	Population	Upper limit of class													Total	$\bar{X}$	S_2
		3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0			
S_1N_1	P_1				2	1	1	2	2		1	2			11	9.4	6.45
	F_2		1	1	6	14	21	10	20	16	5	1	2	3	100	9.3	5.44
	P_2	1		4	5			1							10	5.6	2.05
S_1N_2	P_1							1	3	3	2	1			10	11.0	1.33
	F_2				2	1	4	15	20	11	19	9	10	9	100	11.4	5.51
	P_2	1	2	2	3	1									9	5.0	2.25
S_2N_1	P_1	1		2	3	1	2	1							10	6.3	3.12
	F_2	1	5	12	19	11	16	10	11	5	6	1	1		98	7.7	5.65
	P_2	2	2	2	3	1									10	5.4	6.71

4, Panicle Weight

As shown in Table 4, increase of nitrogen level, increase the variance of the F_2 population, but increase of spacing, decrease the variance value. On the other hand, the comparison between the means of parental and F_2 populations, as given in Table 5, no differences between fertilizer treatments were found at the spacing, but the mean panicle weight per hill is significantly reduced at close spacing regardless the amount of nitrogen applied in F_2 populations. Same is true in IG-65-1 parent, but both nitrogen and spacing influenced the means of panicle weight in Pai-kan-tao parent.

If we divide panicle weight into light (less than 12.0gr.);intermediate (12.24gr): heavy (more than 24.0gr) for S_1N_1 and S_1N_2 treatments, and that light (less than 8.0g) : intermediate (8-20gr.) and heavy (more than 20 gr) for S_2N_1 plot. All three F_2 populations of different treatments showed a monogenic mode of inheritance with nondominance gene action conditioning the difference of these parents. The observed values for S_1 N_1, S_1 N_2 and S_2N_1 are 21:45:14; 28:48:22, and 19:43:16 respectively. The X^2-values between theoretilcal (1:2:1) and observed ratios ranged from 0.7755 to 2.450 ($P=0.50-0.20$) which are acceptable.

Table 4. The means,variances and frequency distributions for panicle weight per hill of parents and F_2 populations at three different environmental conditions.

Treatment	Population	Upper limit of class, gr.										Total	$\bar{X}$	S^2
		4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0			
	P_1	1	5	1	1	3						11	10.61	29.91
S_1N_1	F_2	3	5	13	25	20	12		1		1	80	15.10	30.50
	P_2	1	8	2								11	6.30	5.31
	P_1	2	3	1	3			1				10	13.50	41.59
S_1N_2	F_2	1	10	17	22	26	14	4	3	1		98	16.60	43.18
	P_2		3	4	2							9	9.62	8.79
	P_1													
S_2N_1	F_2	19	25	18	10	5		1				78	8.10	24.48
	P_2	7	3									10	3.80	1.98

Table 5. Comparisons between means of four characters under different treatments as indicated by mean differences.

Comparison	Plant height (cm)			Panicle length (cm)			Panicle number			Panicle weight per hill (g)		
	P_1	F_2	P_2	P_1	F_2	P_2	P_1	F_2	P_2	P_1	F_2	P_2
N_2—N_1 (S fixed)	−0.9	3.8**	5.2**	2.1*	-0.1	1.8*	1.6*	2.0**	−0.6	2.9	1.5	3.3**
S_2—S_1 (N fixed)	−3.0	0.9	10.7**	0.1	-1.6**	0.2	-3.1**	-1.6**	−0.2	-3.9*	-7.0**	-2.5**
S_1N_2–S_2N_1	2.1	2.9**	−5.5*	2.0*	1.5**	1.6*	4.7**	3.7**	−0.4	6.8**	8.5**	5.8**

* significant at 5% level.

** significant at 1% level.

Table 6. Heritability values for 4 traits of F_2 plants at three different environmental conditions.

Classes	Plant height (%)	Panicle number (%)	Panicle length (%)	Panicle weight (%)
S_1N_1	27.96	12.68	0	31.56
S_1N_2	76.96	51.33	0	82.33
S_2N_1	6.93	2.21	0	—

Under the ordinary spacing (22.5 ×22.5 cm), when the nitrogen is increased from 80 kg/ha to 120 kg/ha, the heritability value is also increased from 31.56 to 82.33 %. This fact indicates that for the selection of heavy panicle weight, selection procedures would better be practiced under heavy nitrogen level condition.

II. The effect of environmental conditions on phenotypic correlations of parental and F_2 populations

The phenotypic correlation coefficiants of parents and F_2 populations for six character-relationships under different environmental conditions are estimated and are given in Table 7. Table 7 shows that increase of nitrogen amount or reducing planting spacing did not change all the character relationships of parental populations, except increase the correlation coefficients of panicle weight and panicle number which is caused by the increased amount of nitrogen fertilizer. In F_2 populations, decrease of character associations due to the increase of nitrogen fertilizer under same spacing were found in panicle number and panicle length; panicle weight per plant and panicle number; plant height and panicle number; plant height and panicle length; plant height and panicle weight per plant. However no change in phenotypic correlation between panicle length and panicle weight per plant was found. On the other hand, enhancement of correlation coeficients due to close spacing under same nitrogen level were found in the character associations of panicle number and panicle

length; panicle length and panicle weight per plant; panicle weight per plant panicle number; plant height and panicle length, but the reduce of correlation coefficient found between plant height and panicle number. The above results indicated that the character relationship gave different response to environmental conditions.

Table 7. Phenotypic correlation coefficients of P_1, P_2 and F_2 populations for six character-relations under different environmental conditions.

		N_1S_1	N_2S_1	N_1S_2
Panicle no. Panicle length	P_1	− 0.246	0.407	—
	F_2	0.037	− 0.447**	0.415**
	P_2	0.071	− 0.540	− 0.363
Panicle length Panicle weight	P_1	0.533	0.035	—
	F_2	− 0.128	0.120	0.454**
	P_2	0.032	− 0.004	0.621
Panicle weight Panicle number	P_1	0.383	0.066	—
	F_2	0.368**	− 0.136	0.538**
	P_2	0.266	0.661*	0.423
Plant height Panicle number	P_1	0.319	0.333	− 0.238
	F_2	0.260**	− 0.042	0.110
	P_2	0.176	0.454	− 0.451
Plant height Panicle length	P_1	− 0.385	0.160	− 0.254
	F_2	0.196	− 0.779**	0.501**
	P_2	− 0.036	0.052	0.549
Plant height panicle weight	P_1	0.430	0.098	—
	F_2	0.309**	− 0.008	—
	P_2	0.558	0.527	− 0.077

* significant at 5% level.
** significant at 1% level.

Discussions

Chang(1964)studied eight agronomic traits of a rice cross, showing that close spacing drastically decreased the panicles and grain yield per plant, but slightly decreased other characters. The heritability values estimated for various traits in wide and standard spacings were higher than those in close spacing. From varietal point of view, Chang and Yang

(1966) reported that split application of fertilizers generally out-yielded than the conventional one in both crops, owing to the increase of number of grains per panicle or grain weigth. Besides, close spacing also gave higher yield than the conventional one the weight and length of panicles were significantly increased by split fertilizations but decreased by close spacing. Chang *et. al.*(1967) indicated that different timing of fertilizer application combinations gave different yield. Chang(1968) reported in two Ponlai varieties of Taiwan that added nitrogen, increased plant height and panicle length where as reduced spacing decreased them. Panicle weight was not affected by the increase of nitrogen but decreased slightly with the reduction in spacing. A slightly different result has been obtained in this study as shown in the comparisons of means of parents under different treatments. Present study showed that P_2 (Pai-kan-tao) was highly responsible to environmental conditions, while P_1 (IG-65-1) was slightly or not affected by nitrogen amounts and spacings. These clear contrasts between the means and distributions of the parental populations are good for genetic studies in the hybrid population.

The influences of environmental conditions on the four characters of F_2 populations, however, indicated clearly that increase of nitrogen amount did not or significantly increase the mean values. On the contrary, when spacing is reduced, it did not or significantly decrease the mean and variance values of each character, except plant heigth which is no difference. These results indicated that the responses of these four characters in parental and F_2 populations were different under different environmental conditions.

The heritabilities of four characters are highest in S_1N_2 plots and lowest in S_2N_1 plots, indicating that the optimum environment in this study is the ordinary spacing with increased level of nitrogen. Under this condition, the practice of selection will be the most appropriate.

As defined by Frey (1964) that stress environment would be the one in which performance is low, relative to performance in other environments. This leads to situations in which a particular environment is stress for one attribute or character and-stress for another, and this situation occurs commonly in corn. The results obtained in present study were in consistent with the Frey's findings, which indicated that environmental condition of close spacing was the stress factor for panicle length, panicle number, and panicle weight per plant, but non-stress for plant height. Generally speaking, close spacing is the stress factor and nitrogen level was non-stress factor for parents and F_2 populations in this study, as the former one increased and the latter one reduced the heritability estimates drastically.

The results obtained from this study suggested that the environmental conditions affected the variances and means of parents and F_2 populations at certain level, but how did the environments do on the character relationships of those populations? The data in Table 7 indicated that the environmental changes did not affect the character associations among the parental populations, but changes some character relationships of F_2 populations.

As the agricultural situations like Taiwan, should a plant breeder seek genotypes that are high performing, should he aim his program at development of varieties that will

perform well in a broad spectrum of environment or at varieties highly adapted for special kinds of environments? Comstock and Moll (1963) suggested in general condition that for the first alternative was favored by small genotype environment interaction, the second by large. Therefore, we should select our materials under the environment that could allow the genotypes exhibite fully, which is the best condition, for the practice of selection Ordinary spacing, however, with increased amount of nitrogen will be the best environment for practicing the selection courses of these four characters of rice in this experimental field.

The cultivation environmental conditions as nitrogen amount and spacing did influence the variations and means of parents and F_2 populations at certain levels. But only slightly affected the genetic patterns of each character as the segregation ratios are similar in most of the cases with only the dividing points are shifted under different environmental conditions. Finally, how to translate this basic information obtained into breeders' tools and apply these findings on practical uses in the courses of selection needed further cooperative studies of rice geneticists and plant breeders.

Summary

In order to obtain the information on the variations and genetic patterns of four quantitative characters of a rice cross in different environmental conditions, a cross of IG-65-1 × Pai-kan-kan-tao was used in this study. The data on plant height, panicle number, panicle length and panicle weight per plant showed that the responses of these four characters in parents and F_2 populations were different under different environmental conditions. Monogenic or digenic mode of inheritance differentiating the four characters respectively, were found in most of the cases, indicating that the environment did not affect the genetic patterns but shift the dividing points.

It was found that the heritability value was highest at S_1N_2 for all three characters suggesting that the genetic potential for each character performed best under S_1N_2 (non-tress) conditions. Therefore, the selection of a certain desired character should be under this non-stress condition. The heritability values for panicle length were estimate to be 0, indicated that for selecting this character the process would be better practiced at the later generation.

Further, it was noticed that the environmental changes did not affect the character associations among the parental populations, but changes some character relationship of F_2 populations.

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水稻數量性狀在不同環境下之變異及遺傳型式

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摘 要

爲獲得水稻四數量性狀在不同栽培密度及氮肥量之環境下之變異及遺傳情形，乃利用 IG-65-1 ×稗稈稻雜交組合爲研究材料。在株高、穗數、穗長、和每株穗重之資料中發現，此四性狀在親本及F_2族羣中，對環境之反應均不太相同。在大部分之情況下，均表現單一因子或兩對因子之遺傳現象。此表示環境並未影響遺傳之型式，但改變了其分界點 (dividing point).。

在所有三個性狀中，其遺傳力 (heritability) 均爲在 S_1N_2 之環境下，最高，表示在此環境下進行選拔最爲有效。另外穗長之遺傳力在各環境下均爲零，故其選拔應在較後之世代中進行。由此研究我們獲知每性狀在非限制 (nonstress) 環境下表現較好。此環境爲普通密度增肥區，此亦爲最佳選拔環境。此外亦發現環境之改變並未改變親本各性狀間之相關關係，但改變一些 F_2 族羣中之性狀相關關係。